Ares I Integrated Vehicle System Safety Team

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Complex systems require integrated analysis teams which sometimes are divided into subsystem teams.

Proper division of the analysis in to subsystem teams is important.

Safety analysis is one of the most difficult aspects of integration.

Consequences of Improper Division

- Misjudgment could lead to failure due to
  - Confusion when performing the work
  - Lack of ownership by an engineering group
  - Inability to present a cohesive analysis
- Failure constitutes
  - Missing hazards
  - Missing hazard causes
  - Lack of hazard control
  - Inadequate verification of controls
  - Inefficiency leading to cost overrun and cancellation

Key Factors

- Key factors to consider when dividing analysis between a major system and its elements or subsystems
  - Politics
  - Funding
  - Expertise
  - Clarity
  - Responsibility/ownership

Key Factors

- Politics
  - Corporate lines (divisions) and companies (contractual considerations) that form the teams
- Funding
  - Which team has enough funding to support the major portion of the integrated effort
- Expertise
  - What is the in depth knowledge each team has
- Clarity
  - Can the lines of the division be clearly defined

Key Factors

- Responsibility/ownership
  - Owner of the hardware/software
    - Most important factor since it usually includes the other factors
  - Owner of controls (hazard mitigation)
    - The team that owns the hardware/software
      - Can implement and/or change the controls as necessary
      - Can affect verification (testing/analysis/inspection)
    - An outside integration team
      - Would need to convince another organization to implement changes or additional controls and verifications

Division of Hazard Reports

Option 1

- Integrated hazard reports and controls would only be owned by the integration team

Option 2

- Divide integrated hazard reports among the integration team and the elements based on who owned the controls for the hardware

Option 3

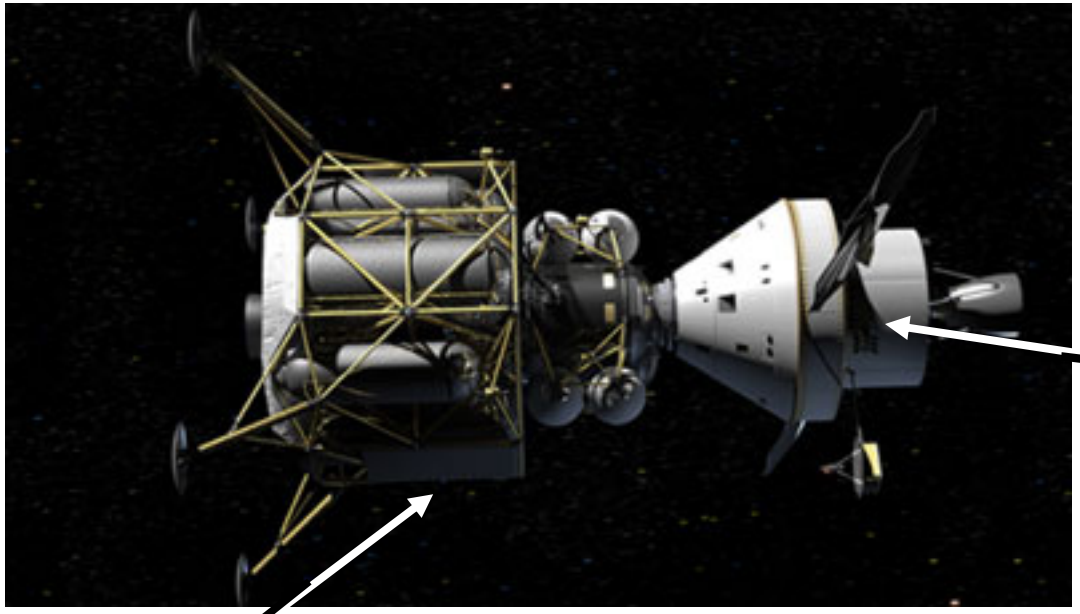
- Integration hazards reports duplicating parts of element reports

Division of Hazard Reports

- Integration team owns all integrated hazard reports
  - Advantage: Single source/consistency
  - Disadvantage: Difficult to change controls if owned by another team
- Divide integrated hazard reports
  - Advantage: Ownership issues resolved
  - Disadvantage: Possible confusion in division
- Integrated hazard reports overlap
  - Advantage: True ownership can reside with hardware owners
  - Disadvantage: Overlap may cause confusion and redundant work

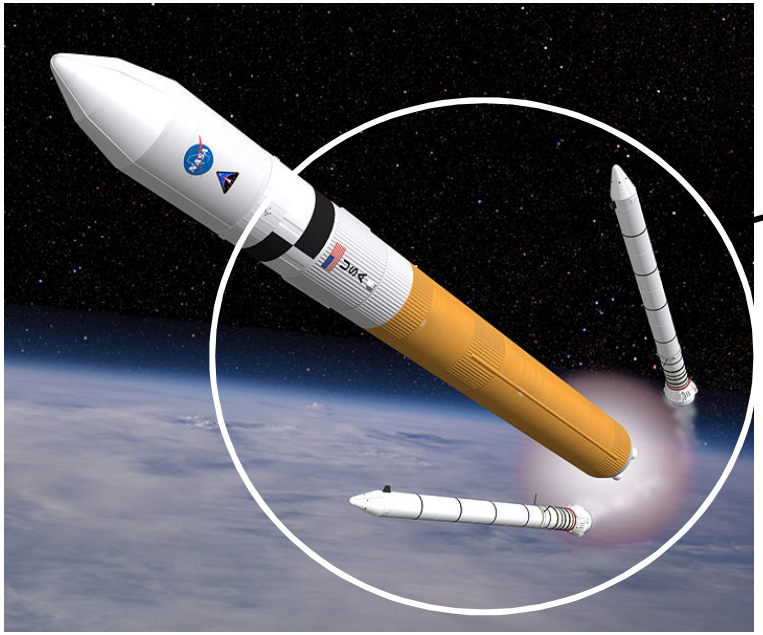
The Ares I Project

- Ares I is a project in the Constellation Program
  - Ares I
  - Ares V
  - Orion
  - Altair
  - Future projects



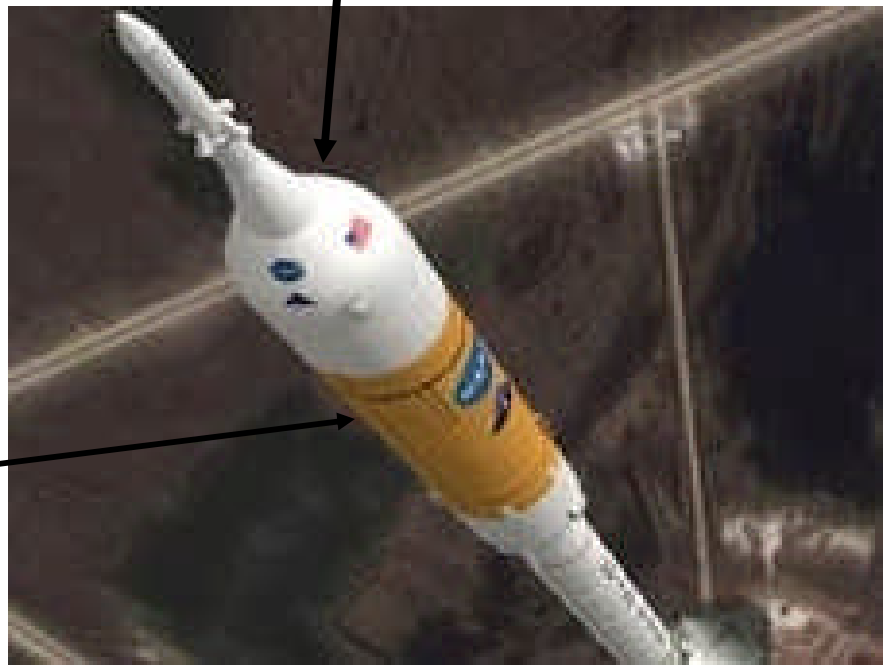
Orion

Altair



Ares V

Ares I

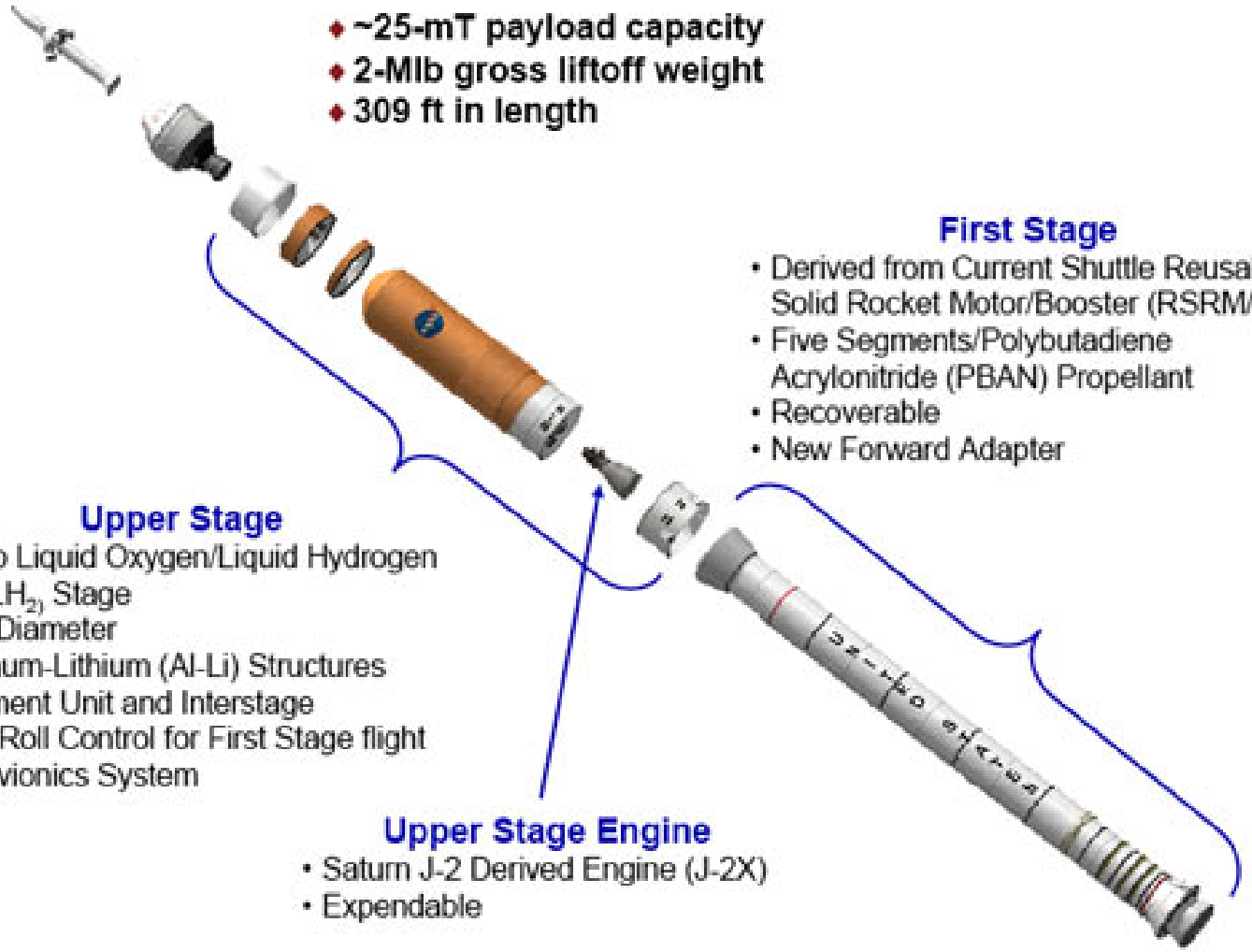


The Ares I Project

- The Ares I Project managed by NASA Marshall Space Flight Center contains
  - The First Stage
    - A solid rocket motor based on the Shuttle Solid Rocket Booster
  - The Upper Stage
    - Similarities to the Shuttle External Tank and other launch vehicles
  - The Upper Stage Engine
    - Based on the J-2, liquid oxygen/liquid hydrogen upper stage engine for Saturn V

Ares I Crew Launch Vehicle

- ~25-mT payload capacity
- 2-Mlb gross liftoff weight
- 309 ft in length



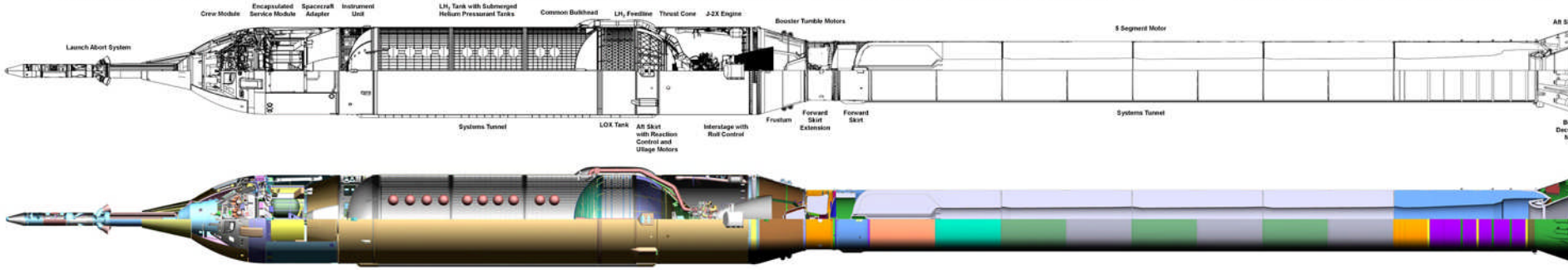
First Stage
- Derived from Current Shuttle Reusable Solid Rocket Motor/Booster (RSRM/B)
- Five Segments/Polybutadiene Acrylonitride (PBAN) Propellant
- Recoverable
- New Forward Adapter

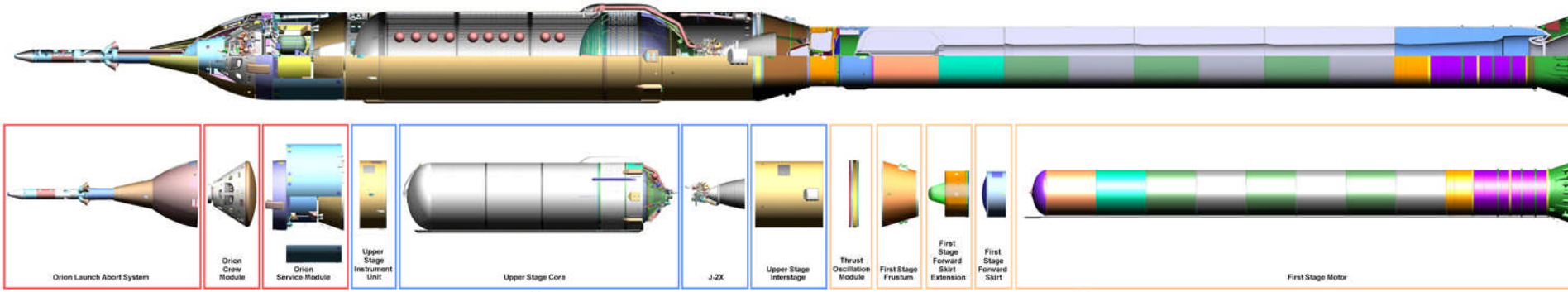
Upper Stage
- 280-klb Liquid Oxygen/Liquid Hydrogen (LOX/LH_2) Stage
- 5.5-m Diameter
- Aluminum-Lithium (Al-Li) Structures
- Instrument Unit and Interstage
- RCS / Roll Control for First Stage flight
- CLV Avionics System

Upper Stage Engine
- Saturn J-2 Derived Engine (J-2X)
- Expendable

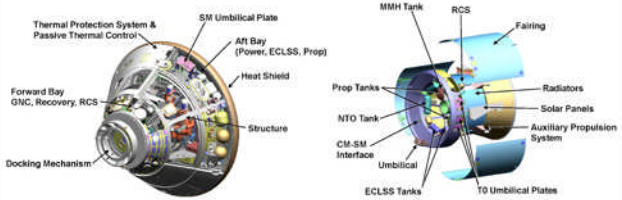
Ares I – A106 Configuration

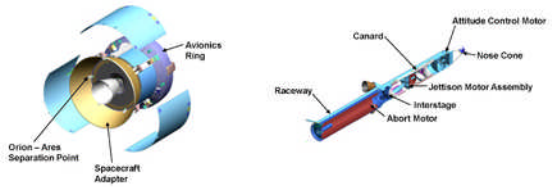
Orion: 606D, Block 1A Shown | **Upper Stage: 97M25000-001 Pre-PDR J-2X: 9R115000A1 V4.0** | **First Stage: EM000700 Rev K**



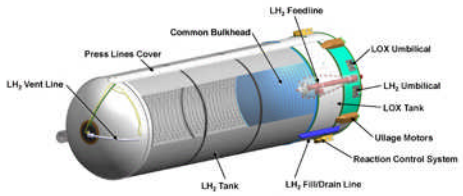


Orion Spacecraft

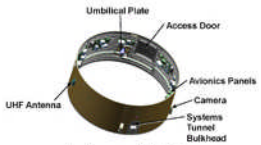




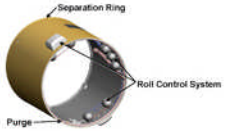
Upper Stage



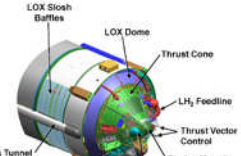
Core Upper Stage

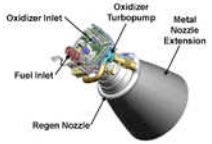


Instrument Unit

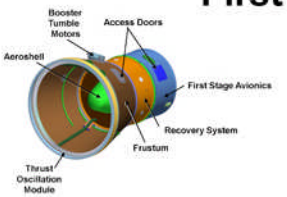


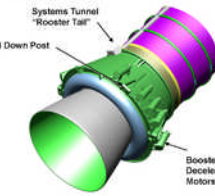
Interstage

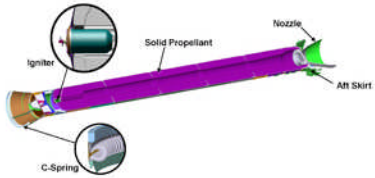


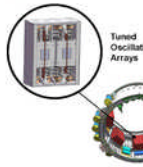


First Stage









Launch Sequence

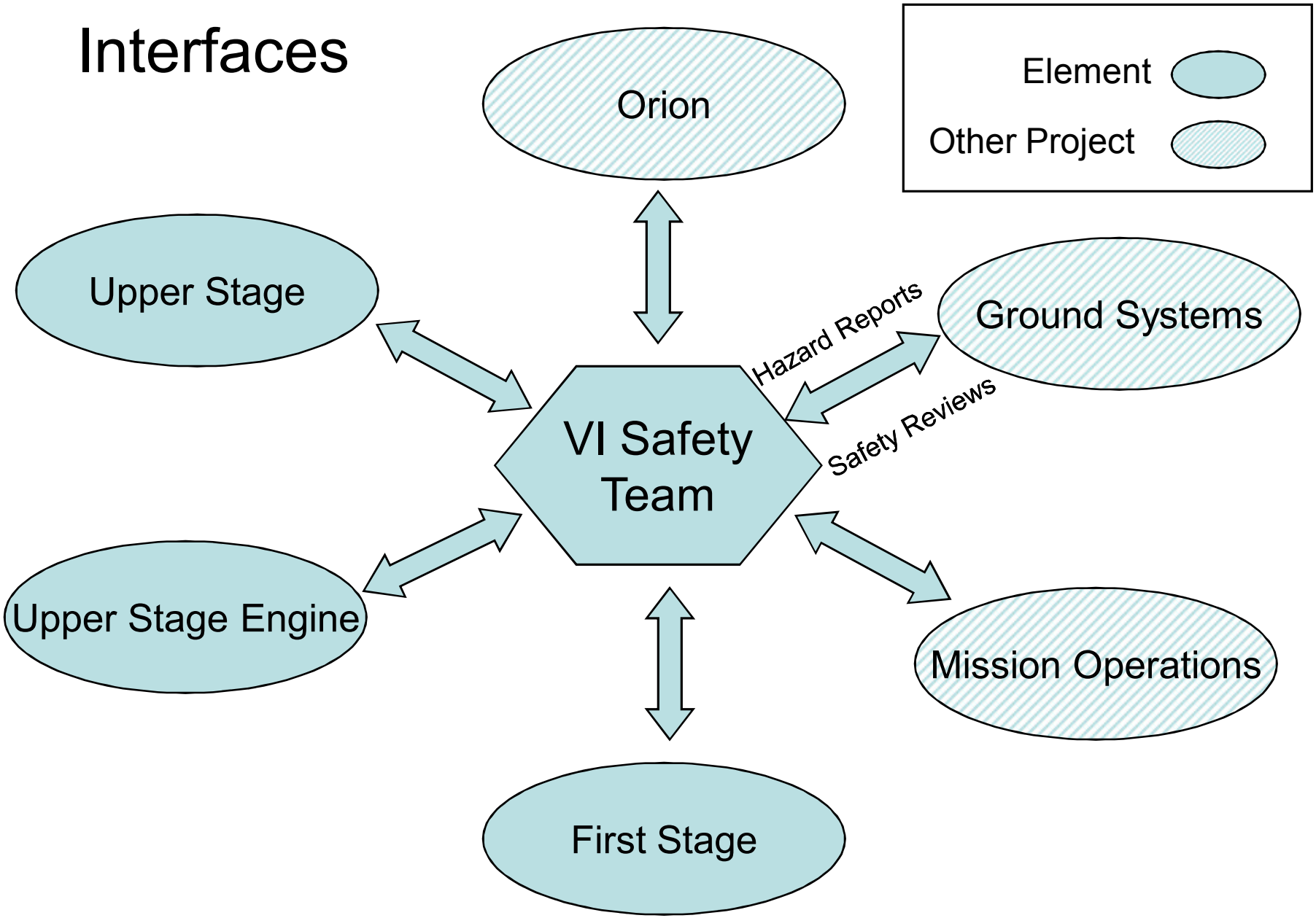
Ares I Political/Funding Aspects

- The Ares I Project is divided by element
  - First Stage (FS)
    - Has a contractor for the element
    - Management is in-house at MSFC (existing working relationship from Shuttle)
  - Upper Stage Engine (USE)
    - Has a contractor for the element
    - Management is in-house at MSFC (existing working relationship from Shuttle)
  - Upper Stage (US)
    - In-house for design
  - The Vehicle Integration (VI)
    - In-house effort

How Ares I Divided Safety Analysis

- Formation of Safety Teams for the Project
  - Each element has a Safety Team
    - FS has a contractor to develop the hazard analysis and hazard reports
    - USE has a contractor to develop the hazard analysis and hazard reports
    - US performs the hazard analysis and develops the hazard reports in house
    - The VI portion of the project performs the hazard analysis and develops the hazard reports in house

Interfaces


Element
Other Project
Orion
Upper Stage
Ground Systems
Hazard Reports
Safety Reviews
VI Safety Team
Upper Stage Engine
Mission Operations
First Stage

Integrated Hazard Report on Ares I

- Example
  - Upper Stage contains a number of controls for hazards for other elements
    - Fuel quality for USE to prevent engine explosion
    - Software control of FS to prevent loss of control/guidance
  - Technically the VI Safety Team owns the hazard but US owns the control

Integrated Hazard Report on Ares I

- Options
  - Document controls in VI reports only
  - Document controls in US reports only
  - Document controls in both reports
- Solution
  - Document controls in US reports
  - VI report contains cause which points to US report for controls

Conclusion

- Division of integrated portion of the analysis must consider
  - Politics
  - Funding
  - Expertise
  - Clarity
  - Ownership